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QUARTERLY PROGRESS REPORT

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QUARTERLY PROGRESS REPORT

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Under this Task Order Contract, RAND is conducting studies of Apollo Contingency Planning for the Advanced Manned Missions Office, Headquarters, NASA. The work is divided into four major areas of investigation: Apollo Reliability and Contingency Planning; Cost Studies; Manned Mars Mission Expedition Requirements Study; and Space Program Planning Study. In addition, during this quarter reports were submitted on two related studies: one discusses some implications of missile development and test experience for the Apollo program; and the other suggests a program of eclipse observations from the moon.

RAND's activities in each of the four major study areas during this reporting period are summarized below.

I. APOLLO RELIABILITY AND CONTINGENCY PLANNING STUDY

A. Reliability Growth During a Development Testing Program

The study of statistical methods for estimating reliability growth during a development program was completed; it is currently in draft report form. Intended for use primarily by statisticians concerned with estimating reliability growth during the Apollo test program, this report considers, in addition to techniques for estimating reliability growth, estimating lower confidence intervals based on test data and simple trend tests for reliability growth. Several potential follow-on studies of statistical methods for estimating system reliability during the development period have been outlined and will be discussed with the Apollo Reliability and Quality Directorate during the fourth quarter.

B. Considerations Relevant to the Apollo Flight Test Program.

Apollo Man-rating and Maturing Requirements. We are delaying completion of this study in order to extend the results to provide greater depth for the several considerations. The questions being addressed are (1) the number of test flights which might be required to man-rate the Saturn V launch vehicle, (2) the number which might be required to mature the Apollo spacecraft, and (3) the rate at which test flights might be carried out. These questions are being studied in part to gain a more detailed insight into the flight-test program for Apollo. In this manner, we hope to gain a better understanding of problems which could cause excessive development difficulty and hence could become likely candidates for contingency planning. This initial look at development test flight requirements uncovered what appeared to be two potential problems requiring study, possibly leading to contingency plans. These problems are discussed below.

The Use of Earth Orbit as a Means of Circumventing Development Problems with the Saturn V Booster. An initial, quick study is being made to determine whether a more detailed study is warranted. Briefly, the study will examine the potential use of the Gemini capsule and Titan II or the Apollo capsule and Saturn I-B to deliver an Apollo crew to earth orbit in the event that problems develop which postpone man-rating the Saturn V. In this manner, the Saturn V need not be man-rated, while earth orbital and even lunar missions are accomplished with the Apollo spacecraft. Implications of this mode of operation to other areas in the Apollo program will also be considered. For example, weight increases in the spacecraft could also be countered through the use of earth orbit delivery of the crew if the Saturn V were to be augmented by, say, strap-on solid propellants. This augmentation would slip the estimated time of man rating and the use of such earth orbital crew transfer could, in these cases, save many months of potential program slippage.

LEM Lunar Landing and Return to Command Module. We understand that the one exception to NASA's philosophy of unmanned precursor testing is the LEM lunar landing attempt. Because of the difficulties inherent in the LEM landing maneuver--the requirements imposed upon LEM subsystems and crew training by the trajectory, the unknown aspects of the lunar environment, and the uniqueness of the event--we felt that a study should be made to determine the need, if any, for an unmanned precursor to the manned landing attempt. Our initial review of the problem convinced us that it was not an appropriate study for RAND to undertake at the present time, for several reasons. First, the scope of the study is likely to be too large with respect to the manpower available for the entire Apollo flight test program. Secondly, the study would require technical assistance from people closely connected with day-to-day Apollo events; such people are found at places like Grumman and NASA Manned Spacecraft Center--not necessarily at RAND. And, finally, the opinion was expressed by RAND people knowledgeable about guidance subsystems used in Air Force programs, that there might not be any real problem in demonstrating the LEM guidance subsystem via earth orbit testing rather than lunar orbit testing. As a consequence, this study proposal was put aside in favor of other work, with the intent of reviewing it again if later information indicates that the study should be undertaken.

Problems Related to Space Suit Design. During this quarter, an investigation involving both physiological and engineering considerations was begun on problems related to the survival of the astronaut and his ability to perform useful work while wearing a space suit--particularly in the lunar surface environment. A report is being drafted which points out a number of basic design, developmental, and operational problems, and which indicates certain paths to their solution.

II. COST STUDIES

A. A draft report has been prepared describing the substantive cost studies completed thus far. The draft report includes chapters detailing:

1. Obligational authority estimates for a 25-year NASA plan for the manned exploration of space, broken down by individual project.

2. Cost estimating relationships developed under this contract for pricing spacecraft by subsystem.
3. Cost estimating relationships--in part previously developed and used in preparing launch vehicle estimates.
4. A formalized model describing the logical structure and all the data flows involved in projecting the obligational authority requirements for a long-range NASA manned space plan (a computer program for mechanizing many of the computations--described under Section B below--is also discussed at length).

B. A computer program (FORTRAN) was developed to cope with a considerable volume of the calculations involved in preparing time-phased estimates of the financial requirements resulting from a given long-range manned space plan. This FORTRAN program and a copy of the card deck has been transmitted to NASA Headquarters for their use.

C. A series of space system task and cost element breakouts was prepared for use in NASA's advanced system studies as a financial data reporting system. Currently the cost, design, and performance information prepared as part of these studies is not done on any uniform basis, in accord with any common set of ground rules. Despite the quality of such estimates, this lack of uniformity makes inter-study comparison difficult. The RAND system attempts to deal with this problem, at least as far as financial data is concerned.

III. MARS EXPEDITION REQUIREMENTS STUDY

The level of effort devoted to this study increased during the quarter so that two sub-studies were completed and two others begun. Examination of previous manned Mars missions studies, Voyager studies, and plans (in part) for Mariner and other space probes, has been carried out to determine the data requirements from probes. These have been informally transmitted to NASA. Additionally, a sub-study of instrumental techniques for analysis of the Mars atmospheric composition has been completed and is in draft form.

Currently we are examining a number of techniques for determining density as a function of altitude, as well as techniques for mapping the Mars surface.

In the next quarter we expect to carry out study of Mars radius measurements and of surface, load-carrying capability. Preparation of a draft summary report on Mars environment measurements and techniques will follow the radius and load-bearing sub-studies.

IV. SPACE PROGRAM PLANNING

A. The first draft of a report describing the logical structures of goals, missions, and space program planning was completed. An unclassified version was sent to Messrs. Gray and Lord for their study and participation in the continuing effort. A multidisciplinary RAND research team has been formed to carry the initial work to a proper conclusion. We expect that this group will further refine the goal concepts by relating them, in a more formal manner, to missions.

B. Design and operational aspects of an orbiting launch platform for advanced lunar and planetary missions are being investigated in conjunction with our over-all study of the reliability implications of long-term space missions. From our extensive review of the literature, it appears that insufficient attention has been paid to two important aspects of orbiting launch platforms which may, in the end, determine their feasibility and desirability as compared to other approaches. These aspects are:

1. The logistics supply cost, in terms of the propellant that must be supplied to the platform to maintain a desired orbital altitude. The space platform will require large amounts of propellant at the lower, dense altitudes to keep its station. At altitudes above 200 n mi the propellant requirements are expected to diminish rapidly.
2. The logistics cost in terms of possible frequent crew transfers necessitated by man's limited tolerance to the radiation at the higher altitudes (above 200 n mi).

This investigation will consider the sensitivity of the platform altitude to atmospheric density, radiation, fuel requirement, radiation tolerance, and proposed mission. It will also enumerate the operational features of the launch facility on such a station and, together with the results of the study described in Section C below, will provide inputs to the logistics build-up and maintenance study described in Section D.

C. Studies of the scientific payloads for lunar missions, and for space station laboratory operations were undertaken during this quarter. Emphasis on the nature of this payload or instrumentation was the result of our initial look into the question of manned vs. unmanned missions. It was decided to disregard this implication initially and instead concentrate first on the nature of the scientific work to be done in these environments. The determination of whether or not this work should be manned or unmanned will follow after the requirements or tasks are laid out.

This work has proceeded slowly, primarily because of the necessity for defining the sub-goals of the NASA scientific goal. It has also been necessary to re-examine what is meant by exploration. A review of work to date has, for example, shown intense concentration on the geology of the moon and, in general, on the question of the origin of the earth--or comparative planetology. The study is also considering the question of how scientists can make use of the moon and of a space station as an experimental environment.

During the next quarter we hope to clarify these two goals more fully and to identify scientific goals, missions, tasks, and operations both on the space station and on the moon.

D. The result of the research outlined in the above Sections B and C will provide inputs to the logistic build-up and support structure being developed to enable us to evaluate the relative merits of an Earth Orbiting Space Station, such as the MORL, versus a Lunar Laboratory as a scientific and development base. Previous NASA reports and studies have been used and are being used extensively, to obtain some base-line transport costs, quantities, schedules, etc. In addition, U.S. Navy experience in arctic and antarctic logistics has been tapped extensively.

By the end of the next quarter, we hope to determine if there can be a cost competition between the MORL and the Lunar Base.

E. Work has begun on the problem of defining an integrated strategy for space exploration. Although much of the more philosophical aspects of this work will be a part of the task described in Section A above, details of proposed experimental sequences will require study of specific technologies in order to determine the feasibility of the approach. Thus, for example, an expanded role for Ranger as an observational aid in performing both the Apollo and post-Apollo Lunar Program has been examined and looks attractive; a draft report on this has been completed.

F. Research on guidance has continued. The applicability of the Air Force standardized guidance system to future NASA missions has been investigated and a report is in preparation.

V. ADDITIONAL STUDIES

A report was submitted on a study of the application of Air Force missile experiences to development and test planning for the Apollo program; this was RM-4229-NASA, Some Implications of Missile Development and Test Experiences for the Apollo Program, by S. I. Firstman and D. N Morris. Relevant experiences in numerous areas of missile technology were surveyed and implications of these experiences for the Apollo program were determined. These implications, reported primarily in the form of guidelines and concepts for development and test practice, are largely at the policy and program guidance level, since it is intended that the major benefits of this survey will be to those concerned with the management and coordination of the Apollo program.

Another report submitted during this quarter was RM-4249-NASA, A Suggested Program of Eclipse Observations from the Moon, by G. F. Schilling. This report presents a brief description of a proposed series of unique scientific experiments to be performed on the moon. Later program phases would provide

for long-term extensions of the scientific program to manned missions in earth orbit and to manned flights between earth, moon, and the planets. The report is intended to draw the attention of program planners to the potential advantages of adopting eclipse observations as one of the major scientific objectives of the Apollo and post-Apollo programs.